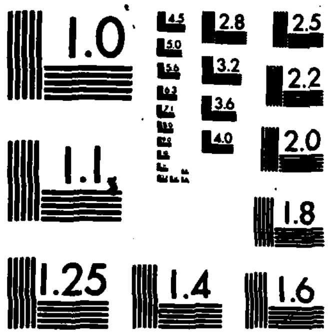
AD-A137 679   MOBILIZATION AND DEFENSE MANAGEMENT TECHNICAL REPORTS SERIES CREATIVITY A..(U) INDUSTRIAL COLL OF THE ARMED FORCES WASHINGTON DC  J D LANG APR 83 NDU/ICAF-83/010   1/1

UNCLASSIFIED   F/G 5/1   NL

END
FILMED
DTIC




MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

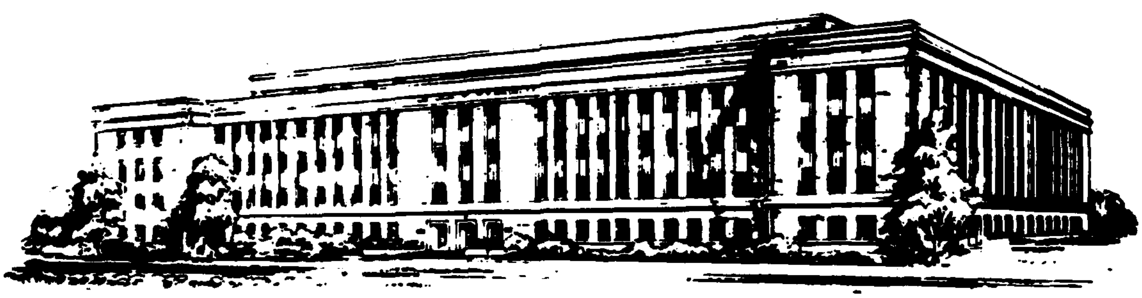
2

NATIONAL DEFENSE UNIVERSITY

**MOBILIZATION AND DEFENSE MANAGEMENT TECHNICAL REPORTS SERIES**

AD A137679

# CREATIVITY AND INNOVATION IN DEFENSE TECHNOLOGY AND STRATEGY







INDUSTRIAL COLLEGE OF THE ARMED FORCES

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

| REPORT DOCUMENTATION PAGE | READ INSTRUCTIONS BEFORE COMPLETING FORM |
|---|---|
| 1. REPORT NUMBER NDU/ICAF 83/010 — 2. GOVT ACCESSION NO. AD-A13 | 3. RECIPIENT'S CATALOG NUMBER 7679 |
| 4. TITLE (and Subtitle) CREATIVITY AND INNOVATION IN DEFENSE TECHNOLOGY AND STRATEGY | 5. TYPE OF REPORT & PERIOD COVERED IR #12, AY 82-83 |
| | 6. PERFORMING ORG. REPORT NUMBER |
| 7. AUTHOR(s) JAMES D. LANG, LTC, USAF | 8. CONTRACT OR GRANT NUMBER(s) |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS INDUSTRIAL COLLEGE OF THE ARMED FORCES FORT LESLEY J. MC NAIR WASHINGTON, DC 20319 | 10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS |
| 11. CONTROLLING OFFICE NAME AND ADDRESS INDUSTRIAL COLLEGE OF THE ARMED FORCES FORT LESLEY J. MC NAIR WASHINGTON, DC 20319 | 12. REPORT DATE APRIL 1983 |
| | 13. NUMBER OF PAGES 60 |
| 14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) NATIONAL DEFENSE UNIVERSITY FORT LESLEY J. MC NAIR WASHINGTON, DC 20319 | 15. SECURITY CLASS. (of this report) UNCLASSIFIED |
| | 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE |

16. DISTRIBUTION STATEMENT (of this Report)

UNLIMITED APPROVAL FOR PUBLIC RELEASE

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

N/A

18. SUPPLEMENTARY NOTES

N/A

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

N/A

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report takes a broad look at how technology and strategy interplay in determining defense plans and force structure. Creativity and innovation are shown to play a critical role, not only in developing new weapons systems, but also in developing new strategies, tactics, and in training and leading armed forces. The vital national resources of creativity and innovation are examined in terms of their current and potential roles in these areas. Creativity and innovation are seen to hold the key to defense effectiveness in the future.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

20. The defense research and development system is examined with emphasis on determining areas where creativity and innovation can be most effectively applied. Also studied is the notion that creativity and innovation can be fostered and managed and that "innovating organizations" can be created.

The DOD Laboratories are seen to serve a seldom appreciated role at a critical point in the research and development (R&D) process where technology focus, integration and transition are of paramount importance. Operational requirements and diverse, selected technologies must be carefully integrated in order to achieve a mature system concept.

Creativity and innovation are found to be important too in non-technical areas such as management methods, and organizational design, coupling and communications. The nature of creativity and innovation, as well as their importance, is discussed. The objective is to achieve an understanding which can lead directly to action and improved defense capability.

Recommendations are offered, primarily with reference to the defense R&D sector, for improving the technology development process and for coupling it more closely with doctrine and force structure development.

THE INDUSTRIAL COLLEGE OF THE ARMED FORCES
NATIONAL DEFENSE UNIVERSITY

INDEPENDENT RESEARCH PROGRAM REPORT

# CREATIVITY AND INNOVATION IN DEFENSE TECHNOLOGY AND STRATEGY

by

JAMES D. LANG, LTC, USAF

A RESEARCH REPORT SUBMITTED TO THE FACULTY

IN

FULFILLMENT OF THE RESEARCH

REQUIREMENT

RESEARCH SUPERVISOR: THOMAS S. MYERCHIN, LTC, USA

THE INDUSTRIAL COLLEGE OF THE ARMED FORCES

APRIL 1983

## DISCLAIMER-ABSTAINER



| Accession For | |
|---|---|
| NTIS GRA&I | X |
| DTIC TAB | ☐ |
| Unannounced | ☐ |
| Justification | |
| By | |
| Distribution/ | |
| Availability Codes | |
| Dist | Avail and/or Special |
| A-1 | |

# ABSTRACT OF STUDENT RESEARCH REPORT
# INDUSTRIAL COLLEGE OF THE ARMED FORCES

| NAME OF RESEARCHER (S) | TITLE OF REPORT |
|---|---|
| LANG, James D.<br>Lieutenant Colonel, USAF | Creativity and Innovation in Defense Technology and Strategy |
| **SECURITY CLASSIFICATION OF REPORT** | **REPORT NUMBER** |
| Unclassified | M IR# 12 |

## ABSTRACT


This report takes a broad look at how technology and strategy interplay in determining defense plans and force structure. Creativity and innovation are shown to play a critical role, not only in developing new weapons systems, but also in developing new strategies, tactics, and in training and leading armed forces. The vital national resources of creativity and innovation are examined in terms of their current and potential roles in these areas. Creativity and innovation are seen to hold the key to defense effectiveness in the future.

The defense research and development system is examined with emphasis on determining areas where creativity and innovation can be most effectively applied. Also studied is the notion that creativity and innovation can be fostered and managed and that "innovating organizations" can be created.

The DOD Laboratories are seen to serve a seldom appreciated role at a critical point in the research and development (R & D) process where technology focus, integration and transition are of paramount importance. Operational requirements and diverse, selected technologies must be carefully integrated in order to achieve a mature system concept.

Creativity and innovation are found to be important too in non-technical areas such as management methods, and organizational design, coupling and communications. The nature of creativity and innovation, as well as their importance, is discussed. The objective is to achieve an understanding which can lead directly to action and improved defense capability.

Recommendations are offered, primarily with reference to the defense R & D sector, for improving the technology development process and for coupling it more closely with doctrine and force structure development.


THIS ABSTRACT IS UNCLASSIFIED

ICAF FORM 56 1 FEB 75 (REVISED)

TABLE OF CONTENTS

## EXECUTIVE SUMMARY

During these times of rapid growth in scientific knowledge and technology, creativity and innovation play a critical role not only in developing new weapons systems, but also in developing new strategies, tactics, and in training and leading armed forces. This report examines the system and processes which determine United States defense capability in an attempt to identify how creative and innovative efforts can be more effectively applied. The central theme of the report is that effective application of creativity and innovation in both technology and strategy is absolutely essential. The report focuses however, on the defense research and development process.

In the defense research and development (R & D) process it is seen as important to achieve a balance between those efforts which focus on the threat and are aimed at countering Soviet strengths, and those efforts which take advantage of our strengths and are designed to exploit Soviet weaknesses. Creative (i.e., inventive) and innovative (i.e., progressive) thought is appropriate in both cases. The need to "modernize" relies on creative and innovative efforts also to change the traditional ways that the services have been doing business. The idea that creative and innovative efforts must be focused at appropriate times during the R & D process is discussed to show that there must be management control of the creative process. It is seen to be a process that involves convergent as well as divergent efforts. The nature of innovation is also mentioned.

The role of the DOD laboratories in the critical early phases of R & D is also studied here to see where and how creativity and innovation can be applied to improve the technology development and transition processes.

Creativity and innovation is seen as important not only in developing technology but, perhaps of more importance now, in improving management methods. Examples of innovative management approaches are reviewed with the objective of learning how to create "innovating organizations" where creativity and innovation are fostered and effectively managed.

Creativity and innovation are seen also to be strong national resources which are vitally important throughout all sectors of society. This report looks at the advantage that free people of the West have in natural incentives to invent, innovate, to develop and spread technology and to devise new "ways of doing business." Some recent ideas on the nature of innovative people and organizations is reviewed also to improve understanding of the art of managing creativity and innovation.

Some of the more prominent conclusions of the report are:

1. The qualitative lead in technology over the Soviets is tenuous and there is need to upgrade strategic and tactical doctrines, training and professional leadership qualities.

2. Defense managers should take better and more selective advantage of creativity and innovation.

3. Creativity and innovation is needed throughout non-technical defense endeavors as well as in developing technology.

4. There is an urgent need for defense R & D to become a more innovating process.

5. The DOD labs are at a critical point in the development process where effective creative and innovative efforts have high leverage in improving force structure and its application.

6. Organizational structures should be creatively downsized where appropriate to improve effectivess and efficiency.

7. The fundamental need is not just to do the same jobs better but rather to also determine completely new and better roles for all defense participants.

Some of the significant recommendations:

1. Defense managers should act now and effectively to create organizational climates that foster creativity and innovation.

2. Incentives to encourage and reward creative work should be established by all levels of DOD management.

3. The art and science of designing innovating organizations should be widely studied.

4. The trend in organizational design should be toward more autonomous, decentralized units with stronger coupling with other organizations.

5. R & D managers should improve the balances between: (1) specialization and generalization; (2) adaptation and innovation and (3) divergent and convergent creative efforts.

6. R & D lab managers should lead the way in improving communications among key players in technology development and in integrating diverse technologies into optimum system concepts.

7. Prototypes and technology demonstrators should be emphasized.

8. Defense service schools should establish instruction in creativity and innovation.

# CHAPTER I

## INTRODUCTION

"Human knowledge has outpaced our imagination and even more our willingness to change."

--Edward Teller

We live during a period of rapid growth in scientific knowledge and technology which is coupled tightly to military, social, political and economic changes throughout the world. Alvin Toffler, in The Third Wave, discusses the complex, dynamic interactions of modern technology and other forces of change and resistance to change which compete now throughout the world for influence in shaping the future.[1] He argues that we are in a period of change which surpasses the industrial revolution in its scope and importance. He offers suggestions to help us welcome the future, to help us understand the need to change and to help us constructively manage those changes.

This report will also look to the future but with a narrower field of view. The purpose here is to focus on the system and processes which determine future United States defense capability. That, still rather broad, topic involves a complex interaction between technology and military strategy in determining the Nation's military force structure. Technology provides us with the means to develop weapons systems of various capabilities which should ideally be blended together in a preplanned fashion to yield a force structure which can be called on, if needed, to implement the military objectives of our overall national strategy. There are examples however, of weapons systems which were developed and demonstrated before a corresponding military strategy was in hand. Dr. Robert Cooper, the Director of the Defense Advanced Research

Projects Agency (DARPA) points to nuclear weapons and space surveillance systems as illustrative of two technological advances which profoundly affected strategy after implementation.[2] The point is that technology and strategy are related in an interactive sense; sometimes new technology "pushes" new strategic thought and sometimes (although much less often than desired) new strategic or tactical requirements "pull" the development of technologies along a desired track.

Important to both technology and strategy or tactics development is the role of creativity and innovation. A central theme of this report is that effective application of creativity and innovation in both areas is absolutely essential in these changing times. James Fallows, in National Defense, expresses deep concern that the interplay between new technologies, strategies and tactics is sorely neglected and furthermore, that far too much emphasis has been placed in the wrong areas of technology development.[3] We will examine his and others' criticisms of current weapons development practices and explore the challenge that results in attempting to creatively fix organizational and systemic problems that detract from achieving a balanced interaction between technology and strategy.

The broad treatment here on creativity and innovation with respect to defense technology and strategy will serve to set the stage for an in-depth view of defense research and development. A limited but special emphasis will be placed on Air Force research, exploratory and advanced development, and the role of the Air Force Wright Aeronautical Laboratories (AFWAL) at Wright-Patterson AFB, Ohio. My goal in all of this is to provide a proper perspective for the importance of creative thought and innovation throughout all components

of the defense technology and strategy community, and to specifically address the powerful role of creative thought in the research and development process.

Creativity and innovation are "buzz words" today, but they are vital concepts. Jack Morton in Organizing for Innovation recognized this when he said,

> " . . . a viable enterprise does not invest large effort in innovation just because it is fashionable, or to solve short-term problems. Innovation pays only when it is part of a (management) strategy for long-term survival, for adaptivity and growth in an ever-changing world."[4]

## CHAPTER II

## DEFENSE RESEARCH AND DEVELOPMENT

Technology means many things to many people. Technology in the larger sense encompasses all research and development which leads to the production and fielding of defense systems. In Secretary of Defense Weinberger's Annual Report to the Congress for FY 84 it is further explained that:

> Research, Development, Test, and Evaluation (RDT&E) activities lay the groundwork for the acquisition and deployment of affordable, reliable, and supportable weapons and equipment needed to give our armed forces the means to carry out their assigned missions.[1]

There are four major categories (and corresponding number designators) in this developmental process: Basic Research (6.1), Exploratory Development (6.2), Advanced Development (6.3), and Engineering Development (6.4). The first two categories are treated as the "Technology Base." It is from resources applied to the Technology Base that new ideas and "technology breakthroughs" occur. Department of Defense (DOD) sponsored research at universities and DOD laboratories accounts for the large share of Technology Base activities. Advanced Development is the phase in which technology requirements are translated from ideas to proven concepts. Industry efforts, under contract from DOD, play an ever-increasing role in this phase. The issue of efficient transfer of ideas and concepts from inventor to implementer, and proper integration of all interests (for example: ultimate user, force planner, logistician) takes on increasing importance during this and subsequent phases. Engineering Development is that portion of the development cycle where proven and demonstrated ideas are packaged into systems destined for generally

large-scale production. During this phase complete cadres of program office personnel serve to manage what has matured into an "acquisition system."[2] Activity in development of weapons systems in this phase takes on an ever-increasing operational development, and a decreasing technical development nature. The Federal Government has decided to limit its own (in-house) R & D activities generally to those areas, such as military R & D, which should not be completely left up to the private sector. Even within defense R & D however, universities as well as industry and the DOD laboratories play complementary roles in originating and developing new weapons systems.

In order to accomplish research and development (R & D), the military services have organized along somewhat common models that have evolved throughout technologically oriented industries. The R & D function is usually found in a separate line organization so that specialized expertise can be developed and concentrated on the unique scientific, engineering and technical management challenges which permeate what is now called the world of "high-technology." The Air Force, for example, has a separate organization dedicated to research and development of new weapons systems. The Air Force Systems Command, headquartered at Andrews AFB, Maryland shares an R & D mission with Air Force Logistics Command, but while AF Systems Command concentrates on new systems, AF Logistics Command performs R & D to permanently modify and support existing systems. Within AF Systems Command there are separate organizations to further specialize in conducting and/or managing: (1) basic research (the Air Force Office of Scientific Research--now organizationally found under the Director of Laboratories), (2)

exploratory development and the conceptual, early part of advanced development (the Director of Laboratories), and (3) the systems oriented part of advanced development, engineering development, and a follow-on phase: operational systems development (the Deputy for Systems). The important function of independent testing during the developmental phases of a system's life is monitored, managed or conducted within AF Systems Command by the Deputy for Test and Evaluation. Furthermore, the Air Force Test and Evaluation Center (AFTEC) exists as a completely independent test agency which concentrates on operationally oriented testing. The idea is for AFTEC to provide evaluations of systems during the latter phases of development when military effectiveness can and must be judged so that expensive production and deployment decisions can be made wisely.

There are critics who charge that the system of defense research and development is too cumbersome and ponderous and that it takes far too long and costs far too much to develop an idea into a useful operational system. There are critics who charge that the system also does not properly select from new or even current technologies which could be used to drive costs down, speed up schedules and, very importantly, reduce the complexity to make new systems easier to operate and maintain, and probably cheaper to own during their life-cycle. There are critics too who argue that bureaucratic inertia has built up so much that new technologies are developed without properly considering whether the resultant systems would fit into operational strategies or tactical plans. Along those lines, there are critics who argue that not enough emphasis goes into <u>first</u> determining strategies and tactics and <u>then</u> in developing appropriate technologies and systems.

These charges raise important elements of concern and they have profound implications for the need to change. It is critical that we examine these types of criticism so that we can begin to create solutions to those classes of problems that exist now or will possibly exist in the future.

## Countering The Threat

While I do not suggest that our national military strategy nor R & D policies be formulated solely to counter a perceived Soviet threat, I think it is extremely important to know as much as practical about Soviet military capabilities and R & D efforts. With that knowledge in hand it may be too tempting however, to rely on what I perceive as a defensive approach--that of countering enemy strengths head-on with only "symmetrical moves" of our own. That approach, although needed in some cases, puts us in a purely reactive mode and places the initiative with our opponent. Rather, I concur in our use of an aggressive, positive R & D approach where our strengths and enemy weaknesses are both exploited. This approach, which has been at the forefront of our defense strategy through many administrations, is based on firm rationale and a deep understanding of the character of our nation. In effect, the decision was made not to attempt to match the Soviets in quantities of material or manpower but rather to concentrate on developing and maintaining a qualitative edge, based on technology, in weapons systems, tactics and training. This approach relies heavily on our cultural strength of individual freedom and initiative, and on our corollary ability for technological innovation.

Force modernization is one way of describing this approach. DOD emphasis

has thus been on weapons systems research, development and acquisition programs; but as the Air Force Association points out; "The strong common denominator of all these modernization programs must be improved war-fighting capability."[3] And such capability includes readiness, sustainability, intensified realistic training, refined tactics and a complete complement of other modernization changes that reflect sound military strategic thinking and not just technology.

Richard DeLauer, Undersecretary of Defense for Research and Engineering, raised new concern over our historic edge in technology when he said, "The Soviets are eroding the U.S. lead in about half of the twenty basic military technologies that have the greatest potential for changing capabilities in the next ten to twenty years."[4] He went on to discuss the need to stop technology transfer from West to East. This transfer, which covers the spectrum from basic research through fully developed products, has become more prevalent now when much of the world has become highly proficient in technology, and communication is rapid and widespread.

## The Need To Modernize

Under Secretary Delauer sees the defense mandate indeed "to modernize the force" but he seeks also to correct what he perceives as lack of emphasis on improving the acquisition process. Furthermore, he is pushing to improve planning in the Planning, Programming and Budgeting System (PPBS) so that programs are made more coherent within a planned mission area framework.[5] Secretary of Defense Weinberger has set modernization up as one of the two highest priority "duties" of the Reagan Administration. He says " . . . we

must make up for lost years of investment by undertaking the research and development and force modernization needed to meet threats that may arise in the future." The other priority duty is " . . . to increase the basic readiness and sustainability of our [current] forces so that we could meet an immediate crisis, if one arose."[6] DeLauer's deputy, James P. Wade, Jr. in "New Directions in Defense" went on to say that three initiatives have been offered to improve defense force structure modernization:
(1) allocation of resources by mission area (looking beyond the near term a decade or more), (2) better integration of acquisition costs and schedules into the Planning, Programming and Budget System, and (3) closer look at how new programs will fare in the face of potential Soviet counteractions. Wade also talks to a trend concerning blurring of traditional distinctions between the services, between their missions and between weapons and their command and control systems.[7]

Thus the challenge has been offered anew to question and improve the current and traditional roles of the Services and especially to work at the interfaces between them where serious gaps in effectiveness may exist. David C. Jones, former Chairman of the Joint Chiefs of Staff, said in regards to the Services' rigidity on thinking of traditional missions and methods, "the result of this rigidity has been an ever widening gap between the need to adapt to changing conditions and our ability to do so." He called for better integration in defense planning and more attention to combat effectiveness.[8] Wade went on to say, "It is critically important to have an aggressive science and technology program to maintain or increase our dwindling technological lead over the Soviets."[9] He asked for help from the aerospace industry, on

that occassion, to get the cost of defense systems under control. More emphasis he said, needs to be placed by DOD on: (1) program stability, (2) competition (but to avoid buy-ins), and (3) mission area assessments to help decide what we do not need and therefore on what we should not be spending money. The aerospace industry was asked for help in alleviating the growing shortage of engineers and help in finding " . . . other than traditional ways of doing things--particularly cross-service, multi-mission approaches."[10]

Such comments reflect the desire by the very highest levels of management in DOD for creative and innovative thinking. These same leaders also recognize that both planning and R & D efforts are abolutely critical to the long-term success of any organization. They recognize too that historically companies have reacted to tight money and recession by cutting expenditures that are not tied to current operations.[11] R & D and other capital expenditures are usually the first to be cut, but within defense, there has been a determined effort to hold the line on R & D funding. Within defense R & D there has been however, a rigorous scrubbing down of programs so that the key technologies which offer highest long-term payoff can be sufficiently funded and developed.

Total Research, Development, Test, and Evaluation (RDT&E) funding requested by the President in his FY 84 budget is $29.6 billion which represents 10.8 % of the total DOD budget and a 27% increase over FY 83 authorizations in RDT&E. The portion used for research, exploratory and advanced development programs (6.1 to 6.3a, also called the Science and Technology program) is $4.8 billion, a 13% increase distributed as follows to give most emphasis on advanced development: $850 million for basic research

(a 4% increase), $2.7 billion for exploratory development (a 5% increase), and $1.2 billion for advanced development (a 43% increase).[12] Although these figures appear promising at first look, it is important to realize that the Soviets now spend twice as much as the U.S. on RDT&E whereas in the mid 60's they spent less than us.[13] William Perry in his review of Fallows' book National Defense points out that the magnitude of the Soviet's effort in R & D and procurement allows them to field not only overwhelming quantities of military weaponry but lately they have fielded modern weapons (e.g., MiG-27 aircraft, T-64 tanks, SS-18 missiles, Typhoon submarines) that are "at least as complex and expensive as their U.S. counterparts."[14] Whereas the U.S., because of national priorities, cannot compete with the Soviets in terms of both quantity and quality, the Soviets have amply funded efforts to compete in both areas.

Contemporary Criticisms

One of the most articulate critics of modern defense is a member of the so-called military reform caucus. James Fallows in his book National Defense sets out on a high purpose--to focus the defense debate on issues that are of extreme military significance. In the first chapter he discusses "realities" such as U.S. economic limits, the unpredictable nature of the "threats" an American defense must contend with, and the importance of intangible qualities (the friction of war) like weather and human error.[15] William Perry, former Undersecretary of Defense for Research and Engineering, in his critique of Fallows' book offered two additional "realities" (which were briefly mentioned previously); namely, the reality that modern Soviet weapons are increasingly

complex and effective fighting machines (and some of their newer aircraft are probably more complex and expensive than their U.S. counterparts), and the reality that the Soviets can and do spend twice as much as the U.S. on equipment procurement.[16] Both Fallows and Perry, as well as numerous other critics, are in firm agreement on the need to improve the procurement system. Disagreement comes about, of course, on how to improve the system and whether change should be of evolutionary or revolutionary form.

Fallows decries the "managerial" approach to defense which came into predominance during the McNamara years. He cites the "failure of managerial defense"[17] and as Perry agrees, he " . . . correctly points out the overemphasis on one-dimensional cost-effectiveness analysis, and the underemphasis on leadership qualities."[18]

Fallows' treatment of leadership, careerism and other military personnel issues is, in Perry's words, " . . . provocative and thoughtful, and makes a real contribution to the national debate on defense,"[19] One key personnel issue is related to the critical role that creativity and innovation must play in the military. Fallows' fundamental plea may be interpreted as a call for new solutions, new strategy, tactics, new uses of technology--in other words, effective reform. However, he overemphasizes technology as a culprit. Perry points out ". . . the notion that <u>technology</u> per se increases equipment costs has no basis in reality; it is <u>complexity</u>, not technology that is the culprit."[20] In addition to some useful advice given by Fallows, Perry reiterates current DOD-thinking by offering three ways of dealing with the "quantity/quality quandary." First is to "take maximum advantage of the geopolitical factors in our favor - geography, allies, economic strengths, and

political stability. . . . Second, we should take advantage of our better motivated and better trained manpower. . . . Third, we should use our technological advantage _selectively_ to offset Soviet numerical advantages by _finessing_ them whenever that is possible."[21] Perry further relates that technology " . . . offers the U.S. its best hope for _increasing_ equipment reliability and _decreasing_ equipment cost."[22] But in counterpoint, Fallows states that current practice is for designers to push " . . . technology without distinguishing between the innovations that simply breed extra layers of complexity and those . . . that represent dramatic steps toward simplicity, flexibility and effectiveness."[23] Gansler, in his book _The Defense Industry_, further emphasized this point by reference to the expression "because we can do it, we must do it." He claims that " . . . engineers establish the military 'needs' based on promised technological advances."[24] So the proper leadership and management challenge appears to involve selective focusing of creative and innovative talent toward both strategic and proper technological needs.

Harvey Brooks offers a note of bleak pessimism concerning overreliance on the technology factor when he says "It might he argued that the doctrine of U.S. superior innovative capacity has become a psychological equivalent to the Maginot Line in prewar France."[25] He questions the permanence of Yankee ingenuity and the U.S. capacity for innovation, and like Fallows, he decries the faith we have placed in technology as a substitute or surrogate for all-round military capability.[26] Brooks' concern over the health of Yankee igenuity raises one of the more serious questions regarding national will and attitudes; in effect, he questions not only the ability of U.S. managers to

foster and direct innovative efforts but in addition he questions whether the American historic penchant for innovation is obsolescent.

Criticism regarding RDT&E funding of the past has been expressed, among others, by Gansler who faults the large shift in post Vietnam RDT&E funding from technology base efforts to engineering development and acquisition programs,[27] and by Secretary Weinberger who recognized the "50% decrease in buying power (in the technology base programs) that occurred during the 1960's and early 1970's," but has " . . . provided for increases [13% for FY 84] to compensate partially for the 50% decrease . . . ."[28]

Other critics of defense R & D have looked at management. York and Greb in their postwar history of military R & D state that, "Of all the trends and events in the administration of military R & D during the past 10 years, surely the decline and demise of the Presidents' Science Advisory Committee is the most important."[29] That committee provided a useful check and balance in the military R & D system to help integrate programs across service lines without having a vested interest in them. Secretary Weinberger is attempting to provide similiar oversight authority by establishing three new Assistant Secretary of Defense positions to strengthen the Office of the Under Secretary of Defense for Research and Engineering. "An Assistant Secretary of Defense (Research and Technology) will be established to improve our approach in selecting the best technology programs to achieve and maintain a qualitative lead in deployed systems . . . . An Assistant Secretary of Defense (Development and Support) will be established to provide increased management attention to the development of those military capabilities represented by deployed systems and equipment, and to provide an improved focus on

acquisition objectives." The third position represents an upgrade to Assistant Secretary status of the position of Deputy Under Secretary of Defense (Communication, Command, Control, and Intelligence).[30]

One further recommendation for critical review of the defense acquisition system is Norman R. Augustine's book, Augustine's Laws. It is a superb, humorous, and " . . . irreverant guide to traps, puzzles and quandaries of the defense business and other complex undertakings."[31] All such thoughtful critiques of current methods, especially in defense technology and strategy, cry out for (and in some cases offer) creative and innovative solutions. It is the promise of finding better ways that now prompts us to look in-depth at creativity and innovation.

## Chapter III

## THE IMPORTANCE OF CREATIVITY AND INNOVATION

Creative and innovative thought and action is an absolutely critical requirement throughout all sectors of society. Its importance to the revolutionary growth and development of our nation is historical fact. Continued growth is also fundamentally dependent on these traits. National security, as well as social and economic progress depends on continuous renewal, improvement and effective use of these vital resources: creativity and innovation. They are most important in meeting the challenge to freedom posed by the Soviets. We cannot however count on improvements in technology alone to offset Soviet quantitative advantages in military force structure. Nor can we divert attention from technology, since the Soviets are now emphasizing and fielding military equipment with "comprehensive qualitative improvement."[1] The Air Force Association, among others, also argues that "The fragile advantage of the U.S. and its allies in tactics, training and tecnnology must be exploited to the utmost."[2] Our national defense strategy as Dr. Robert Cooper, head of DARPA, points out, " . . . has been to try and maintain tactical superiority technologically and to rely on whatever deterrent effect the threat of 'first use' [of nuclear weapons] may have." Cooper goes on to postulate that technology (through creative exploitation) may profoundly affect strategic planning. "The next generation of advanced surveillance systems and precision-guided standoff weapons may provide a conventional military power so formidable as to rival in the tactical arena the deterrent effect nuclear weapons have had on strategic war." He further

states that, "Two key technologies were most important in deterring conflict among super powers in the recent past; nuclear weapons technology and its various associated delivery systems, and space surveillance technology--systems for ballistic missile warning and intelligence gathering and warning."[3]

Creative and innovative ideas are all important in achieving these technological advances, as well as in the national and military strategy arena. Brian Twiss could have spoken of strategic planning or other fields of creative endeavor when he said, "The effectiveness of research and development depends on the quality of ideas. Creativity is needed both in the formulation of project concepts and in the solution of problems arising during development. Thus the need for creativity is widespread."[4] This notion for use of creativity over a range from totally new concepts to new twists on existing situations, will be explored later when we look deeper into the nature of creativity. But for now it is important to understand that we should be mostly concerned not with new ideas that are consistent with the current way of doing business--but rather with good ideas that do not quite fit into the "organization's" current mode.

Jay Galbraith cautions however that "Industry has a poor track record with this type of innovation. Most major technological changes come from outside an industry." On a more promising note he goes on " . . . to describe an organization that will increase the odds that such non routine innovations can be made."[5] His ideas have received careful attention by leaders of industry and government. Later we will look at some steps being taken now within the Department of Defense and by other organizations to become more "innovating organizations."

## The Advantage of Free People

> "The West has an advantage in technology, partly because it represents a larger pool of industrially more advanced nations. But the underlying reason for the West's advantage is that the organization and system of incentives in the centrally planned Eastern economies are less suited to invention, innovation, and the diffusion of technology than their private enterprise counterparts. . . . lack of competitive pressure and poor communication and cooperation between research and development organizations and the users of technology also hinders change. The result is a lag in both the development and the spread of technology."[6]

But the "lag" of the Soviet Union and the "advantage" enjoyed by the West is in danger if cooperation ebbs in the Western World, communication is hampered, and incentive to achieve creative results is replaced by incentive to maintain the status quo. There is strong evidence that we are losing much of our advantage. The "lag" mentioned above has been measured, and it, in fact, is dwindling.

The Soviets often must import technologies they need in order " . . . to circumvent systemic blockages--red tape, production bottlenecks, factory resistance to innovation and a host of other problems that impede [use] of their own technology."[7] The phrase 'technology transfer' has been applied to one means the Soviets use to circumvent their weaknesses. They probably do not have the flexibility nor inclination to reduce "systemic blockages," so they instead resort, very successfully up to now, to import of technology. They go after the developed technologies, if they can, to bypass large, apparently inefficient, portions of their R & D structure. We in the western world, however (theoretically at least) are free to alter our organizations and methods in an effort to remove blockages to communication, creativity, and technology transfer. But we can also pursue alternate means of obtaining existing or of developing new technology for example, by seeking out other

domestic or foreign sources, through publications or conferences, or even by forming consortia of R & D personnel whose specific purpose for organizing is to improve communications and idea sharing.

There is concern, expressed by Franklin P. Johnson, partner in a leading venture capital investment company, " . . . on the part of American industry that we have become the prototype shop for the rest of the world. In other words, we build the first models--but when it comes to running large-scale efficient production companies we lose the battle to foreign competition."[8] Apparently then, we need to focus efforts on the engineering development and production end of the R & D spectrum, for in defense most of our problems lie in those areas. The authors of "The Winds of Reform" article in Time magazine also agree that problems are serious in these later stages of defense R & D.[9]

Some specific technologies are now recognized for their high potential so that national leaders are calling for creative efforts to be focused in order to improve chances for their successful development. In regards to the revolutionary role of key technologies, Dr. Cooper, DARPA Director, offers some creative thoughts when he says,

> "Five technical areas are contributing to this revolution in conventional weaponry:
>
> Advanced Missilery
> Stealth
> Microelectronics and Artificial Intelligence
> Surveillance Sensors and Image Understanding
> Space.

> . . . we may reasonably expect that the 90's will see major breakthroughs in each, with the consequence of producing startling new standoff weapons. . . . By the year 2000 deterrence of tactical warfare will likely be a reality. . . . Massed forces in warfare will become obsolete and regional warfare will largely be unknown."[10]

But creativity in developing and in applying new technology is not the only area of interest to defense leaders. Foreign policy experts see a need for creative and innovative thought in using economics as well as technical strength to "encourage Soviet cooperation."[11]

In other endeavors of general interest creativity is important. Indeed, in decisionmaking where elaborate tools exist to help the decision maker, it is recognized that, "The best decision cannot be made unless the best option is among those that are considered. . . . decision analysis serves only the function of choosing betweeen options that have already been identified."[12] Creative thought is required to develop most "best options" in these changing times. In many cases however, simply attempting analysis will suggest new alternatives that had not been thought of before.

Defense Creativity Needs

"The distinguishing feature of modern American defense has been the pursuit of the magic weapon."[13] So says Fallows in his interpretation of creative effort which has been misplaced. He talks of a search for "weapons that will make victory automatic," and the effect of technology dominance being " . . . a lineage of weapons in which each generation of plane, tank, missile, ship, costs between two and five times as much in construction money as the previous one."[14] He goes on to chastise the emphasis, within the Department of Defense, on selecting systems and plans which counter threats statically--

or one-for-one rather than by exploiting weaknesses and by use of maneuver and new dynamic military thought.[15]

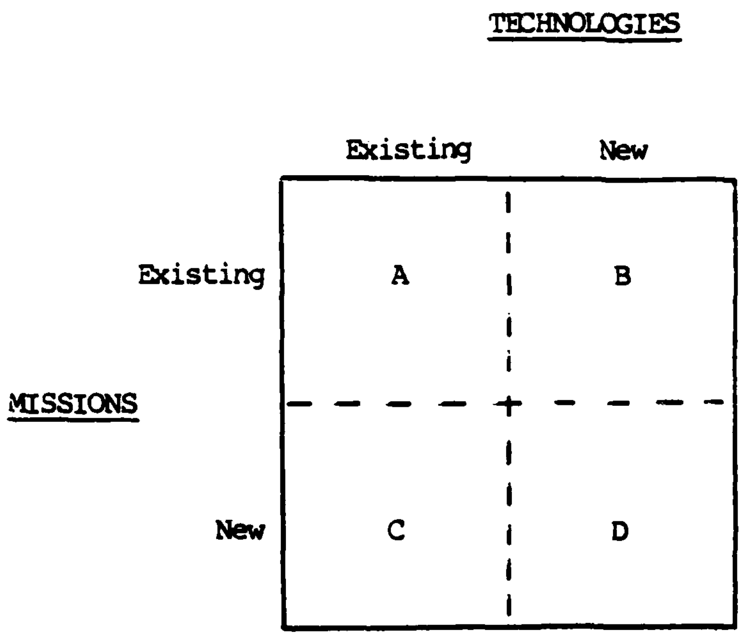
Willis M. Hawkins, a former vice president of Lockheed in his article "Lessons from Aerospace," specifically addresses the quantitative methodologies which sometimes can prove "success" in spite of conflicting judgement based on other more qualitative considerations.

> "Our very success may have sowed the seed of self-destruction in the following ways: [(1) we] may have developed systems management into such a cult that we cannot escape our own creation . . . . [2] We cannot make up our collective mind about anything . . . . [3] We have created the hardware competition to avoid judgement calls. [and (4) In the late 50's DARPA was formed to keep creativity alive] but in many respects this has had the opposite result. . . . DARPA seems to relieve the services of creative responsibility and free them for endless political campaigns--a new form of systems fever--rather than using the techmmical talents at their disposal for creative attacks on real requirements."[16]

Fallows also decries, " . . . the culture of procurement, which teaches soldiers that their function is to buy complex weapons rather that think about how to adopt plans and weapons to an uncertain environment. . . . "[17]

Let us pause to briefly look at the role DARPA plays in defense creativity. According to William J. Perry, "The Defense Advanced Research Projects Agency (DARPA) serves a key role in DOD, vigorously pursuing hi-risk and hi-payoff technologies that have revolutionary implications for future weapons systems. DARPA's task is to provide 'venture capital' for selective fast-moving technologies where exploitation may significantly enhance our defense posture."[18] Note that DARPA's charter centers around hi-risk and the use of creativity and innovation.

The following technology/mission matrix may help us see conceptually where creativity can be applied in defense.




THE TECHNOLOGY/MISSION MATRIX

The matrix is arbitrarily divided into four sectors. In reality there is a continuum of classifications for weapons systems. The degree of technology maturity and the intended system mission determine a point in the matrix. For example, old technology systems lie to the left side of the matrix (e.g., sectors A and C in the matrix, associated with F-4, F-15A and F-16A aircraft, and M60 tanks) whereas the vertical dashed line represents state-of-the-art in technology (e.g., F-18, and M1 tank), and the right side involves prototype or "brassboard" and lab technologies (sectors B and D) which tend to be of high risk in production. The vertical (missions) scale relates to traditional systems (and traditional missions) at the top (e.g., sectors A and B, associated with fighter aircraft for counter-air, tanks for counter-tank, battleships for close-in counter-ship) and nonstandard, risky missions and systems at the bottom (e.g., sectors C and D, associated with chemical weapons, remotely driven/piloted vehicles, etc.). DARPA's charter concentrates on the revolutionary technologies and non-standard missions found

in sector D. Fallows, however, argues that most DOD effort is spent in sectors A (cheap) or B (expensive). He appears to argue for most, if not all creative effort, to be placed in sector C. The point is, however, that creativity is needed in all areas. In the top left corner, for example, creativity can be used in training or in combat to adapt an existing system to accomplish a given 'classical' mission in the best way. Creativity is perhaps more obviously needed in the bottom right corner for developing totally innovative technologies in completely new applications (like space warfare, for example).

The U.S. Army has taken strong measures to foster creative thinking. It is Army Research, Development and Acquisition policy, "To create an environment that encourages innovation and is receptive to new approaches . . . ."[19] Several strategies have been developed to help meet those objectives. They are to : (1) emphasize long range planning, (2) create a center for innovative excellence, (3) implement meaningful changes to the acquisition process, (4) improve the technology base program, (5) create forums for unsolicited ideas, (6) move creative people to key positions, (7) teach creativity and reward innovation in Army school systems, (8) develop an incentive program to encourage (creative) professional writing, and (9) develop attitudes that will provide opportunities to try new ideas--and accept failures.[20] The Army has even set aside a "reservation"--the 9th Division--with a specific mission that relates directly to sector D on the technology/mission matrix; that is, to innovate--to develop and test new operational, logistical, management, leadership, and technological concepts. The Division is not constrained by use of traditional doctrine or equipment. They seek out creative people and concepts. It is definitely a high-risk, potentially high-payoff experiment.

DOD leadership has also made very strong efforts to foster creative solutions to defense problems. A series of 32 actions which comprise the DOD Acquisition Improvement Program, were initiated by the former Deputy Secretary of Defense Frank C. Carlucci in April 1981. They represent "major [innovative] changes both in acquisition policy and the acquisition process itself."[21] They are very important too in that they demand creative and innovative management at especially the program management level. In September 1981, Secretary of Defense Weinberger established the Defense Council on Integrity and Management Improvement which has three primary missions: (1) to identify and pursue management improvements in DOD, (2) to stimulate and act as a forum for innovative ideas, and (3) to ensure follow-up.[22] "The Council's emphasis . . . has already led to . . . more rapid development of innovations in the Services . . . ."[23] In his report to Congress, Secretary Weinberger goes on to explain that he seeks a balance in new technology and strategy.

> "To ensure that we get the best return from our scarce modernization dollars, we must exploit all the cost-effective technology available to us. Today, we and our allies stand at the threshold of substantial improvements in the capabilities of our conventional forces and weapons systems--if we can develop weapons that prove reliable in "real world" conditions, and if we can develop innovative tactics to take advantage of new or improved technology."[24]

Use of creativity is encouraged because, "Our strategy for coping with future developments in conventional warfare must not rely on technical means alone. We must seek to encourage our combat personnel to take the initiative in developing new concepts to employ our forces as skillfully as possible."[25] And one of the military professional organizations also reminds us: "The key to success in warfare is the ability to take initiatives, thus setting the

course of the battle."[26] Such human factors are also recognized by DOD as evidenced by the following:

> "The military success of the Israelis in Lebanon and the British in the Falklands must be accounted for on a much broader basis than just equipment performance. The Israelis and the British prevailed because of the quality of their manpower and leadership at all levels; through their thorough planning, superior training, and high-quality intelligence capabilities; and through their ability to conduct coordinated and cohesive combined operations."[27]

## Chapter IV

## CREATIVITY IS NEEDED IN R & D

While human factors are of prime importance, technology offers tremendous additional military capability. The defense research and development activities must therefore focus on effective use of technology. But according to Willis Hawkins, an experienced participant in defense acquisition:

> "Over the past decade and a half the thrust of the U.S. military R & D programs has changed from visionary and daring quests [of] new frontiers to static approaches. . . . Needed are the kind of outreach programs that characterized the Air Force research and development effort in the 1980s and 1960s and produced advanced ICBMs and aircraft."[1]

In discussing the key role that "user requirements" should play in directing R & D efforts, Hawkins cautions that "The customer isn't always right." He concludes that, "It pays to dream. . . . it is nearly always worthwhile to reach a little too far when you build something new."[2]

While DOD tries to ensure "the creation and maintenance of an environment that encourages development of innovative concepts for military products and services that broaden the spectrum of those previously developed by the DOD,"[3] we tend to think only that the desire is to move to the new technologies and new missions sector of the technology/mission matrix. But of probably greater importance is the thrust within DOD to create better ways of managing even that which we do and use now. For example, Mission Area Analyses have been initiated by DOD to "reveal long-range technological deficiencies [and needs, and to prioritize their urgency.]"[4] Those words, however, do not reveal that this must be a continuous, dynamic, creative process and that it must be so designed. The written products of that process, which are

necessary to communicate the R & D and military planners' consensus on technology needs, must be regarded only as "snapshots in time" of a continually iterative process which ideally must involve all military team players.

George A. Keyworth, the President's Science Advisor writes, "It is the 'gray areas,' inbetween the fundamental and more targeted research that are the most difficult to deal with and require the greatest cooperation and shared responsibilities."[5]

Industry Plays a Key Creative Role

Mission Area Analyses involve industry too, most often through contracted studies, but also through the independent research and development (IR & D) programs that companies undertake to keep up-to-speed with defense needs. Congress has scrutinized IR & D closely lately, and recently has added a cap for FY 83 IR & D expenditures. The fear is that too often companies claim under IR & D that type of R & D which is oriented toward product improvement.[6] The benefits of good IR & D are: (1) it provides major contributions to the technology base to help avoid technology surprise, (2) it stimulates competition and creates technical alternatives, (3) it helps reduce risk, (4) it can provide more "technology for the money" because of minimal administration costs, (5) it provides quick reaction and flexibility to meet requirements, (6) it stimulates creativity to explore good ideas without procedural constraints which surround contracted R & D, (7) it yields studies which complement government in-house research, and (8) it permits companies to anticipate potential government R & D requirements.[7] The difficulty for military R & D managers however, is to provide IR & D money appropriately so

that only the above mentioned high goals and truly significant R & D products are incentivized. The role that industry plays in defense R & D should not be understated. "While the Soviet Union must rely primarily on military research and development, the United States is fortunate in possessing a strong private sector that it can draw upon for novel and creative approaches to the improvement of our military forces."[8]

Hawkins points to wasted creative efforts in R & D via the "expenditure of technical talent" to produce "mountains of data" that each seriously competing company needs to submit for most new weapon system program start-ups. When only one contractor will win not only the R & D effort but also the production and life-time update and replenishment contract, there is a lot at stake in submitting a "competitive" initial proposal. Large teams of design engineers create and develop overly detailed designs the vast majority of which cannot be approved. The point is that in technology development, talent is critical. It is far more important to use critical engineering talent when and where it really counts (i. e., in designing, building and learning from "technology demonstrators" or prototypes, or in other specialized stages of R & D, or for product improvement), than for just creating extraneous studies and proposals that have little significance in terms of technology development or technical learning on behalf of the participating engineers.[9] Gansler writes of this and other "barriers" to entry into defense work which discourage new R & D ideas.[10] Smaller, inventor-led firms often cannot compete now in the proposal competition arena but they should be allowed to compete with an R & D product. There is, Gansler says, the "potential for emphasis on cost-reducing R & D efforts."[11] But the high public visibility and accountability of

R & D decisionmakers makes them feel they must minimize risk (even in the early development phases of a program!) This, according to Gansler, leads to defense production by large, well established firms using only conventional ideas.[12]

Fallows, in his argument to redirect technical effort, also brings out the important role of independent testing and evaluation. "In must cases the technical innovations that best serve the military are those that dramatically simplify instead of adding complications. The way to tell the difference is through a ruthlessly honest and realistic testing program."[13] In discussing responsibilities of the Director, Defense Test and Evaluation, Secretary Weinberger says,

> "His assessments play a major role in evaluating program risk and determining any additional test requirements. . . . he is instituting measures to identify problems early in the the test process (and to), use more innovative test techniques . . . "[14]

There is ample evidence that weapons system programs have generally succeeded in terms of performance, but have failed to meet cost and schedule goals.[15] There are many reasons for this, but the overall trend is clear. Gansler contends that there is a lack of incentive for cost reduction in defense systems acquisition, whereas design objectives of R & D in the commercial world emphasize unit production cost as well as technical performance.[16] Tradeoffs among cost, schedule, and performance goals are part of the routine decisionmaking process of every program office. The suggestion here is that creativity needs to be applied to all aspects of a program so that options are developed which involve more than the usual, limited range of possibilities. It is difficult though to keep innovative,

nonstandard ideas alive in a large organization which is determined to eliminate risk and not do anything "wrong" (that is, different).

Eastman Kodak, in their research laboratory, has established a process which is designed to keep creative ideas alive. Even within this organization, which is generally regarded as an "innovating organization," it was recognized that oftentimes ideas with merit were not properly introduced, "sold," justified, or otherwise defended to first or middle-level managers, so that they tended to die a premature death. A new process, created by Robert B. Rosenfeld, Innovation Facilitator of Eastman Kodak Research Laboratories, involves an open minded peer review of new ideas with feedback and some development allowed which would help the ideas mature and perhaps gain objective evaluation before being subjected to critical review by management. The good ideas mature through this process to the extent that they usually gain sponsorship by management as soon as the peer review is complete and favorable.[17] It is useful to see that some successful industries do go to extraordinary lengths in order to foster creativity, and to keep resulting ideas alive.

## The Critical Role of the Labs

> "The DOD laboratories are a set of 73 laboratories, research and development centers, research institutes and development boards which include 60,000 people, $6 billion in capital facilities and equipment, and expenditures of about $5 billion for research and development effort."[18]

The "labs" conduct basic and applied research, exploratory and advanced development up to concept demonstration, and they monitor and "manage" contracted work in those areas which is done by universities or industries. Most of what the labs do relates to the Technology Base which is described as

" . . . the foundation of future military system capabilities. the goal of the Technology Base is first and foremost to maintain technological superiority over potential adversaries and protect the United States from fatal technological surprise. Equally important, the Technology Base must provide a range of innovative options to select from in the formulation of the Advanced Development phase of the Research and Development process. . . . To achieve these goals, the Air Force should pursue an integrated, focused program of Basic Research (6.1) and Exploratory Development (6.2). Basic Research programs provide the fundamental understanding of physical phenomena without which technology cannot be applied confidently. In Exploratory Development, concepts are examined, feasibility is established, and design criterial aimed at technological solutions to specific military needs are developed."[19]

Dr. Robert Hermann, in his report on the DOD laboratories goes on to say:

"Most observers and participants in the DOD acquisition process agree that the DOD does need a strong and viable set of R & D laboratories and centers such as those now in existence. . . . there is nearly universal recognition that: (1) Good work has been and is being done by the labs through in-house work and sponsored efforts . . . , (2) Much of this work has resulted or will result in the transition of new technology into systems now in use by our operational forces, and (3) Most of the functions assigned to these centers cannot reasonably be transferred to private industry."[20]

This latter point is key in justifying the need for the labs, for there are those, like Gansler who see that, " . . . a significant portion of money goes to 'management' of R & D," and then hastily recommend that "Greater efficiency could be achieved by spending those dollars in the private sector, where the profit motive is present."[21] The proper balance between amount of in-house versus sponsored research is difficult to judge but it is extremely important that a balance, not an extreme, be achieved. In-house research could very well be more "efficient" than sponsored research, but that is of secondary importance. What is key is that only organizations like the DOD labs can properly manage the critical jobs of selective focusing and transitioning technology so that application and development of creative, defense technical concepts can be developed in other than a haphazard fashion.

In the ideal case "The Air Force Technology Base program is driven by identified operational, logistics, and personnel needs."[22] In reality however, the opposite is too often true. The optimum process (as described in chapter II) should be more interactive and iterative. Lab personnel skills must therefore include awareness of defense needs.

The truly creative research and development process involves repeated divergent, then convergent (or focused) activity. It is imperative to balance and properly time both types of activity otherwise an R & D process will tend toward ineffective, unrelated or chaotic efforts on one hand, or narrow-minded, overly conservative and unimaginative efforts on the other hand. Selective use of sponsored research can produce new or divergent thoughts and a goodly number of options to choose from. But it seems naive to expect universities or industry to also supply the needed convergence and to focus efforts by selecting options that are best for national defense. That is the role of DOD laboratories. It is difficult then to accept Gansler's contention that the "profit motive" is of significant relevance in the Technology Base sector of defense R & D. The DOD labs must manage the Technology Base program since they exist primarily to bring applied technologies (either from within or from outside the lab) to maturity and to focus them on defense needs.

The Under Secretary of Defense for Research and Engineering, Richard DeLauer has emphasized the role of DOD in determining " . . . requirements in functional areas and to apply technology in these areas as soon as possible."[23] He seeks to double the funding in the Technology Base programs over the next five years and to focus on speeding the transition of technology

earlier for military applications with earlier feasibility domonstrations. In order to do this, DeLauer says now " . . . there is sharper focus of activities with some technology programs being dropped where the payoff is not obvious, even though the technology might appear interesting. We will still carry some broad research programs and look later for possible applications, but not as much [as before]."[24] This method of focusing R & D effort is expected to greatly assist in transitioning (or transfering) technology more rapidly though the development phases. The President's Science Advisor, George S. Keyworth, also stresses the need " . . . to assure that the flow of new knowledge--from universities, industry, and federal laboratories--remains adequate to meet future defense needs."[25] He further discusses technology transfers between defense and public sectors of the nation and says they " . . . take place best when private contractors are active in both military and civilian business."[26] But he stresses that universities play a major role and that since " . . . basic research . . . is the driving force for the technology base, . . . we must exercise special care in making sure it is sustained."[27] DeLauer joins Keyworth in highlighting the need to enhance university research in areas relating to defense preparedness by supporting improvements in research equipment and facilities.[28]

## Creativity is Essential to Lab Effectiveness

It is absolutely essential that DOD labs become effective as "innovating organizations." There is strong evidence that

> " . . . the procurement policies, procedures, and practices forced on the laboratories by legislation and regulation cause an excessive investment in non-productive activities and are so burdensome and counter-productive that innovation is greatly constrained."[29]

Part of the problem too is

> "Lack of funding support [which] is forcing an ultraconservative management attitude among Technology Base managers. With decreasing real resources, laboratories are unable to make commitments to some of the most challenging technology problems--the ones whose solutions offer the biggest payoffs."[30]

Faced with burdensome procedures, low funding, and ultraconservative management attitudes the task of improving lab R & D effectiveness appears formidable indeed. There are additional complicating factors which demand not only creative and innovative research, but which increasingly demand creative management approaches and attitudes as well.

Separate technologies need to be integrated closely, now more than ever, throughout the entire development process. Gone are the days in aircraft design, for example, when the propulsion experts, wing/fuselage aerodynamicists, flight control specialists, structural design experts and others could operate in relative isolation. Nowadays in aircraft design there is the need to blend, not only wings, fuselages and engines but flight controls, structures and above-all the new avionics central nervous system of all modern aircraft. Integration is therefore <u>essential</u> in developing not only systems but even in conceptualizing systems. Managers need not only to guide transition of technology in specialized, functional areas, but from the very beginnings there needs to be some degree of integration (which also has the potential of synergistic leverage) across specializations. The challenge of integrating efforts among diverse state-of-the-art technical specialties and specialists probably, in itself, requires a separate new technical and management specialization. It certainly demands creative solutions. Furthermore there is a requirement for the labs to support the Preplanned

Product Improvement Program ($P^3I$) by assisting in the transition of technology to deployed systems as well as developmental ones.[31]

Lab personnel need to interface with: mission area analysts, threat analysts, operational users (to understand real needs), other R & D experts in the same organization (to effect transfer of knowledge), R & D experts in other organizations and services, Program Managers (to follow-up on concepts passed on to them), logistics experts (to understand their contraints and needs), and supervisors in the home organization (to close the loop on management control). This overwhelming list of desired interfaces points to another creative challenge; namely, how to provide effective communications while ensuring adequate "quiet time" for specialized, creative work to be performed.

In order to focus and integrate diverse technologies on specific technology needs, while maintaining the strengths of functional organization (e.g., up-to-date and in-depth specialized expertise) the Air Force Wright Aeronautical Laboratories have identified "Major Thrust" technical areas. These are more narrow subsets of the Air Force aeronautical systems set of technologies. The current thrusts have different and short-term estimated lives to completion. They are: (1) night in-weather attack, (2) satellite applications, (3) aircraft sortie generation, and (4) supersonic aircraft persistence. A fifth one, large aircraft, is in initial planning stages. The purpose of each Major Thrust is to: (1) provide a focus for Air Force Technology Base programs, (3) assure the availability of required technology capabilities to satisfy Air Force needs at a specified time, and (4) bring to bear the required commitments and resources within the specified time.[32] The

thrust efforts will be managed by a full-time manager with a matrix organization of first level functional area supervisors who in turn, act as team leaders in their specialty. The thrust organization involves all of the laboratories that comprise the AF Wright Aeronautical Laboratories complex, (i.e., Aero Propulsion, Avionics, Flight Dynamics, and Materials). Each of these Thrust areas provides a focus, not only for lab personnel to relate to, but also for the program offices, which follow in the path of technology transition. The Thrusts provide a convenient interface which, if effective, can speed transition while actually fostering more relevant creative effort.

The Flight Dynamics Laboratory has, in addition, taken the lead in emphasizing technology integration and better planning by chartering one of their broad reaching systems engineering branches to serve in assessing technologies across the spectrum of the four laboratories in order to identify gaps and to assist management in integrating diverse technology efforts.

## Organizing for Innovation

The importance of the systems engineering approach, even early in the R & D process, is recognized by Jack Morton in his book. He says that besides knowing and using the tools of basic research, those in applied research (like the labs) must understand and practice the systems method not only because of its problem solving power (and ability to find the best overall solution--or global optimum--for the entire system rather that deal with disparate "best" or local optimum solutions for each specialized part to the detriment of the whole) but because of its "problem posing power." "It is the tool needed to spotlight the most critically needed innovations in the total system and to

develop criteria of effectiveness to help judge alternate potential solutions."[33]

The Wright Aeronautical Laboratories and its member laboratories have recognized that forces which tend to suppress creativity and innovation can be found out and changed. Management and worker attitudes are key elements that have received emphasis in the Flight Dynamics Laboratory through continuing programs in "Managing Change" and "Organizational Development." Workshops, seminars and offsite meetings have addressed the "Creative Environment." A special course, offered by the Air Force Institute of Technology for laboratory managers, goes into some depth on the importance of creativity and innovation and contains very useful references for follow-on studies.[34] But a thorough commitment in all layers of management is essential to foster creativity and to support those who are creative.

The last point for now regarding the importance of creativity and innovation in the labs concerns the critical need to recognized and retain the specialized role that the labs perform. Morton, with experience as a successful AT&T R & D division manager says, "when R & D is too intimately mixed with manufacture, urgent manufacturing problems bring long-term research and development to a halt . . . ."[35] He argues for separate lab organizations even within the R & D process but is careful to point out that "organizational or spatial barriers" that interfere with good communications and technology transition, must be broken down. So he urges awareness of two requirements which conflict but should be made to exist in balance--the need for specialized lab management methods to foster the more abstract versions of technical creativity and innovation, and the need to rapidly develop and

transition ideas and concepts into and out of the labs. It is an equally important management challenge for the labs to more effectively apply new and potentially high leverage technologies to future systems, while better assisting in the development of new operational doctrine and concepts.

## Chapter V

## SOME THOUGHTS ON CREATIVITY AND INNOVATION

Understanding the nature of individual and organizational creativity and innovation is the first step in attempting to manage their use. There is a need to improve organizational creative and innovative processes as well as individual use of those traits. Harry Levinson, in his book Executive, speaks of creativity where,

> "Recently at a professional meeting, a panel of psychologists and a playwright discussed the process of creativity. The gap between the statistics-laden sterility of the psychologists' comments and the rich imagery of the experience that the playwright reported were testimony to how little is yet known about creativity."[1]

Creativity involves the ability to bring into being, orginate or give rise to ideas, concepts, functions or devices. In comparing the processes of invention (i.e. creation) with innovation, it has been said that the difference is the difference between the verbs "to conceive" and "to use" and furthermore that neither is limited to technological ideas or products.[2] Both creativity and innovation refer to change, but to understand each it is first useful to look at one of the psychological instruments which is intended to measure different approaches to problem solving.

### The Real Meaning of Creativity and Innovation

> "The Kirton Inventory is based on the hypothesis that people differ in how they define and solve problems, because of a preference for either an "adaptive" or "innovative" approach to new information and to change. . . . Adaptors . . . tend to take the

> problem as defined and to generate many ideas aimed at "doing things better." [They] try to incorporate new data or events into existing structures or policies. [When in charge, they] prefer well-established, structured situations. [When in organizational settings, they are] essential to the ongoing functions, but in times of unexpected changes may have some difficulty moving out of their established role. . . . Innovators . . . [on the other hand] tend to go around identified constraints and redefine the problem, with solutions aimed at "doing things differently." [They] see new data as opportunities leading to new structures or policies. [When in charge, they] prefer unstructured situations [and when in organizational settings they are] essential in times of change or crisis but may have some trouble applying themselves to ongoing organizational demands."[3]

"The Kirton inventory is not intended to be a measure of creative potential. The hypothesis is that both Adaptors and Innovators are capable of generating creative solutions, but their solutions will reflect their different approaches to problem solving."[4] The point is that creativity and either innovation or adaptation are needed in order to form solutions. "Innovation cannot be divorced from creativity . . . . Without creativity there can be no innovation."[5] So in this report and elsewhere when the call for creativity and innovation is issued it should be taken as call for "doing things differently"--a call for continued, evolutionary reform. It also implies that "doing things better" is overemphasized now in defense technology and strategy. Gansler for one, in The Defense Industry, provides ample evidence of the adaptation orientation of large firms like those in defense contracting. He contributes this to "institutional inertia and cumbersome internal management processes."[6]

Even if people and organizations are redirected to become more innovating, the question may arise as to whether the changes should be driven by operational needs or rather by what technology has to offer. The question is often

key, because of course the answer determines who gets responsibility (and perhaps authority) for initiating and managing the necessary planning activities. But as Galbraith argues in the ideal process, " . . . for innovation to occur knowledge of all key components [must be] simultaneously coupled."[7] The real problem is how to do technology planning better (in a balanced manner), not who should lead the combined effort.

Strong interaction and effective communication among a few key individuals is critical not only in planning but also in transitioning technology from one phase of development to the next. Galbraith says, "The only way to accomplish both invention and transfer is to proceed stagewise."[8] That is, the divergent/convergent thinking that is part of a creative process should be accomplished repeatedly during the entire flow of development. The upswing of a creative cycle can take place in free-wheeling, open, deferred-decision forums (like brainstorming sessions) but then a critical, decisionmaking process should take over to synthesize among options and to then transfer the technology to its next organizational stop. Technology becomes more refined, and better developed along the way so that personnel with different specialized skills are also needed along the way. The one underlying requirement however, is for creative people, and nowadays we need more of those who are innovative and creative.

## Creative, Innovating People

It has been said that there are three types of people: a small fraction which is truly creative, a larger number who may or may not be creative depending on opportunities and their work environments, and the majority who

rarely have a creative thought--and who seek strongly to neither adapt nor innovate but rather to perpetuate the status quo.[9] It is also recognized by many that creative ability is partially inherited and partially learned (although it is more often "unlearned") and it is known that new enlightened educational and management methods can provide work environments which foster creativity.[10] It has also been said that people can be classified into three other categories:

> " . . . the small group of people who make things happen, a little larger group who watch what goes on, and the overwhelming majority who have not the slightest idea of what is happening. . . . (There is a further subset of) those who watch everything that is being done and point out what is wrong with it."[11]

It seems that this latter group is often drawn from the "status quo seekers" mentioned before.

Galbraith offers the following list of qualities of successful innovators: (1) the need to achieve, (2) the need to take risks, (3) "irreverence for the status quo," (4) knowledge of "the business," and (5) varied experience, for "It is the generalist, not the specialist, who creates an idea that differs from the firm's current business line."[12] This last statement must be balanced by the need to foster in-depth specialization through personnel that can also interface with and influence the generalist innovators. In regards to the scientists and engineers who spcialize in technology rather than doctrine, it is known that those specialists have to be the types that can work in areas where little is known. They need to create new ideas and concepts and it is argued that their functional area supervisors must also be creative.[13] The danger in R & D is that "a research organization that is staffed with people who are not creative is sterile."[14]

An interview with Stanford University's Nobel Prize winner Arthur Schawlow revealed, "Discovery has more to do with what you don't know than with what you do know."[15] He stresses experience: "What you hope to develop through experience is scientific taste, some feeling for what's worth doing and what's possible to do."[16] So experience can be helpful, but other research points to a hazard and seemingly contradictory advice " . . . the person with the high creative ability was most useful when he was a relative newcomer to a project or an area . . . after a person had been engaged in an area of specialization or on a project for a relatively long time, the useful work may have consisted in following out the leads developed earlier rather than developing new ones . . . (indeed) the more creative scientists may themselves prefer movement to new projects and areas."[17] Age proved to have no consistent effect nor did career level.[18]

But Schawlow recognizes that in-depth specialist knowledge is not the type of "experience" he relies on; " . . . to discover something new," he says, "you never have to know everything about a subject. You have to know something, but what you really need is to recognize one thing that's not known. And once you realize that you're looking for the gaps, it isn't so hard."[19] It's generally a hunch that starts an inventor on his quest. Alex Osborn explains, "I've yet to meet that 'coldly calculating man of science' whom the novelists extol. . . . If he exists, I doubt that he would make an invention. The creative act of the mind is alike in art and science."[20]

Educational and organizational methods can stifle creativity. David B. Leeson, founder of a comunications equipment manufacturing company says,

> "There's a turn of mind that is very analytical, and that is fostered by a conventional business education. What is not taught is synthesis. Synthesis is the essence of entrepreneurship.

Synthesis has been totally lacking, in my view, in the larger industries. Managers have been trained to be analytical and to find out what's wrong with this or that kind of idea, but not to create something new out of old thoughts."[21]

"Misplaced precision" by advocates of the status quo is often used to argue against adopting creative and innovative ideas. "The power of the human mind in resisting change cannot be underestimated."[22]

Creative people are needed at every step along the way of technology development, but it has been found that those scientist in basic research have different work values and motivations from those in applied research. Those in basic research (e.g., at the universities) identify strongly with values and motivations that emphasize individual, rather than organizational success, whereas those in applied research (like the DOD labs) have a strong orientation towards organizational success.[23] Those in the later R & D phases have an even stronger organizational success orientation which often takes the form of extreme project advocacy.[24]

## Innovating Organizations

The modern management challenge includes creation of an organization that has the proper blend of personnel and facilities, and a realization that, "To work together toward a common goal, specialists [and generalists] need a common philosophy and language at each interface between [them]."[25] Communications and interfaces need special attention as we have seen but there are other recommendations and some specifics to consider.

"Innovation requires an organization specifically designed for the purpose-that is, such an organization's structure, processes, rewards, and

people must be combined in a special way to create an innovating organization."[26] Alternatively, large companies can "develop, within themselves, sub-environments that foster the enthusiasm and entrepreneurial spirit of the small firm."[27] Galbraith says that organizations that want to revitalize themselves need two organizations in one. One is the normal "operating organization" and the other is the innovating organization; however, there must be a process to transition or transfer ideas from one to the other.[28]

"The natural tendency of organizations to routinize, decrease uncertainty, increase predictability, and centralize functions and controls is certainly at odds with creativity."[29] Creativity was accomplished in a more haphazard fashion in the past.

> "In earlier times, such creative activities took place in widely separated times, places and orgainzations. Often the creative acts and their couplings were randomlike. There was no long-term integration of the separate events, and it was difficult to see them as related parts of a single process. Even the innovators themselves had no full awareness that they were involved in a connected process.[30]

But there is a danger in attempting to couple and to "organize" creative efforts. It has been found that tightly coupled " . . . work teams which coordinate their activities closely to attain the team's mission may provide effective means for achieving an objective but . . . may stifle creativity."[31] This becomes readily apparent when during group meetings or in negotiations, when consensus is hard to achieve, people think the last thing they need is a "bunch of new ideas and thus more options to choose from."[32] They fear delay and confusion and thus work to reject ways to do

things differently as well as rejecting additional ideas on ways to do old things better. So while the first impediment to creative thinking is premature criticism, the second is premature closure.

Ten characteristics of creative organizations have been identified: (1) individual challenges on specific undertakings, (2) realistic goal setting by management, (3) immediate feedback for good and bad performance, (4) a reward system to encourage and recognize creativity, (5) openness and tolerance of conflict, (6) cross-fertilization of ideas between specialties, (7) job enlargement by following an idea from conception to practical realization, (8) involvement rather than satisfaction, (9) porous organizational boundaries, and (10) less conformity.[33] Effectiveness of a group of creative people is also enhanced by some degree of continuous inflow of new people.[34]

Peter Vaill recently emphasized the well recognized move "back to basics" in management and the need for managers to concentrate on providing a strong sense of purpose to all in their organization. He affirmed the collateral need to improve long-range planning and to deeply involve middle managers in that since they are "usually better at seeing what the future holds."[35] Also, Thomas Peters' article on these and other 'basics' is definitely recommended reading.[36]

There are questions that must be guided by consideration of the basics. Managers must strike a balance: (1) between freedom for creative workers to follow their own areas of interest and the need to maintain communications and team spirit in an organized effort; (2) in providing opportunities for multi-disciplinary exposure where work efficiency with teams of specialists is needed; (3) in toleration of non-conformity where the organizational culture

stresses conformity; and (4) between personal objectives and organizational objectives.[37] Managers should also strive to "maximize early failure to promote learning."[38] Note that "failure" is expected in about half of the technology demonstration programs. Failure is a fundamental fact-of-life in R & D.

Peter Drucker points out that the key element in determining success of an innovating organization is:

> " . . . top management and especially the chief executive officer. It is not what he does that matters so much. It is primarily his attitude. The chief executive who . . . forces himself into the right positive attitude towards ideas for the new and different will create, through his organization, the attitude and the receptivity that makes innovation possible."[39]

In R & D organizations at all levels, management attitude is critical. An R & D manager, or technical leader, should be imaginative and " . . . he must be of sound technical background but, to be the real spark plug of his group, he personally has to shoot wild at times, and must encourage those about him to do likewise."[40]

Chapter VI

# CONCLUSIONS AND RECOMMENDATIONS

## Conclusions

United States defense policy relies heavily on maintaining a qualitative advantage over the Soviet Union in effectivess of weapons systems, tactics, training and leadership. But our qualitative lead in technology and its weapons systems is tenuous; furthermore, there is need to upgrade our strategic and tactical doctrines, training and professional leadership qualities.

Defense management should take better advantage of two of our most powerful national resources: creativity and innovation. Since technology is advancing so rapidly in these times it is imperative to properly select that which should be developed and then to control and speed up the increasingly complex R & D process that integrates diverse, dynamic technologies and develops weapon systems.

Creativity and innovation is needed too in the overall defense planning process which establishes new strategies, tactics and technology needs. They are needed also to improve the interaction among the Services and the missions that are assigned. And they are needed by troops in the field as well as throughout the entire leadership and management hierarchy of DOD.

There is an urgent need for defense R & D to become more innovating. And there is a need to focus R & D management efforts at key points along the development path where technology must transition from one group of specialists to another. Technology focus and integration, team building, network building, and effective communications across organizational interfaces all deserve utmost management attention.

The DOD labs are at a critical development focal point--where technology and doctrine short and long-term planners, defense contractors, operational users, and lab R & D managers must interact to achieve a generally common understanding of realizable force structure options. Many organizations do not fully appreciate the role that such applied research efforts play in paving the way for new ventures. In particular the critical role of the labs needs to be better understood by DOD managers so that selective technologies can be identified, developed and demonstrated before they take form for the first time in an unproven and costly application. The labs can exert tremendous leverage in preventing technical difficulties from traveling "downstream" where production ramifications are expensive.

There is critical need to tailor adaptation and innovation strengths to gain improvement in effectiveness for other DOD organizations. The era of "bigger is better" should be replaced by "small within big is better" as an organizational trend.

The fundamental need is to apply creativity and innovation not just in doing the same jobs better but rather in helping to determine completely new and better roles and relationships among defense, industry and university personnel. Properly organized and controlled, creativity and innovation offer a tremendous potential for improved defense capability.

## Recommendations

Defense managers (especially those in R & D and planning) should act quickly and effectively to create organizational climates that foster creativity and innovation. There should be incentives to encourage and reward

creative work. Defense managers should continue to emphasize the need for more creative and innovative efforts in defense planning, doctrine and force structure determination as well as technology development. And they should appreciate better the inherent inertia to perpetuate the status quo.

Defense managers should reexamine organizational structures while keeping in mind that bigger is probably not better. The trend should be toward more autonomous, decentralized units with improved and stronger coupling and better transition mechanisms with other organizations. The art and science of designing innovating organizations should be widely studied.

R & D managers should reexamine and improve the balances between specialization and generalization, adaptation and innovation and the balance between divergent and convergent creative efforts.

R & D lab managers should lead the way in tying together technology possibilities, long-range force structure and doctrinal planning efforts, and operational user requirements so that truly optimum defense systems, concepts and designs can be realized early in the R & D process. Along these lines, the "quick prototype" or technology demonstrator has high leverage, since we "learn more from the use of new hardware than from endless paper exercises."[1]

Defense service schools and other training institutions should establish instruction in defense creativity and innovation and they should create educational environments that encourage innovation as well as adaptation.

---

[1]Hawkins, "Lessons from Aerospace," p. 72.

## FOOTNOTES

### CHAPTER I (Pages 1-3)

[1]Alvin Toffler, The Third Wave. (New York: William Morow, 1980).

[2]Robert S. Cooper, "The Coming Revolution in Conventional Weapons," Astronautics and Aeronautics. October 1982, p. 73.

[3]James Fallows, National Defense. (New York: Random House, 1981).

[4]Jack A. Morton, Organizing for Innovation. (New York: McGraw-Hill, 1971), p. 73.

## FOOTNOTES

### CHAPTER II (Pages 4-15)

[1]Caspar W. Weinberger, Annual Report to the Congress, FY 84. (Washington, D.C.: 1983), p. 269.

[2]Department of the Air Force, Air Force 2000. (Washington, D.C. 1982), p. 242.

[3]Air Force Association, Air Force Association Policy for 1983. (Washington, D.C.: 1983,), p. 3.

[4]"Washington Scene," Astronautics and Aeronautics, September, 1982, p. 30.

[5]James P. Wade, Jr., "New Directions in Defense," Astronautics and Aeronautics. September, 1982, p. 44.

[6]Weinberger, Annual Report to the Congress, p. 4.

[7]Wade, "New Directions in Defense," p. 45.

[8]David C. Jones, "What's Wrong with our Defense Establishment?" New York Times Magazine, 7 November 1982, p. 1.

[9]Wade, "New Directions in Defense," p. 46.

[10]Ibid.

[11]Harvey Brooks, "Notes on Some Issues on Technology and National Defense," Daedalus, Winter 1982, p. 2.

[12]Clarence A. Robinson, Jr., "Special Report: Fiscal 1984 Aerospace Budgets," Aviation Week and Space Technology, 7 February 1983, p. 19.

[13]Weinberger, Annual Report to the Congress, p. 21.

[14]William Perry, "Fallows' Fallacies," International Security, Spring 1982, pp. 175 and 176.

[15]Fallows, National Defense.

[16]Perry, "Fallows' Fallacies," pp. 174 and 175.

[17]Fallows, National Defense, p. 19.

[18]Perry, "Fallows' Fallacies," p. 176.

FOOTNOTES

CHAPTER II (Pages 4-15)

[19]Ibid., p. 177.

[20]Ibid., p. 182.

[21]Ibid., p. 180 and 181.

[22]Ibid., p. 181.

[23]Fallows, National Defense, p. 49.

[24]Jacques Gansler, The Defense Industry (Cambridge: MIT Press, 1982), p. 103.

[25]Brooks, "Notes on Some Issues on Technology and National Defense," p. 130.

[26]Ibid.

[27]Gansler, The Defense Industry, p. 99.

[28]Weinberger, Annual Report to the Congress, p. 270.

[29]Herbert York and G. Allen Greb, "Military Research and Development: a Postwar History," Bulletin of the Atomic Scientists, January 1977, p. 26.

[30]Weinberger, Annual Report to the Congress, p. 82.

[31]Norman R. Augustine, Augustine's Laws (New York: American Institute of Aeronautics and Astronautics, 1982), jacket.

FOOTNOTES

CHAPTER III (Pages 16-25)

[1]*Air Force Association Policy for 1983*, p. 2.

[2]Ibid.

[3]Cooper, "The Coming Revolution in Conventional Weapons," p. 73, 74.

[4]Brian C Twiss, *Managing Technological Innovation* (London: Longman Group, 1974), p. 117.

[5]Jay R. Galbraith, "Designing the Innovating Organization," *Organizational Dynamics*, Winter 1982, p. 6.

[6]Franklin Holzman and Richard Portes, "Trade, Technology, and Leverage: The Limits of Pressure," *Foreign Policy*, Fall 1978, pp. 81, 82.

[7]John W. Kiser, "Trade, Technology, and Leverage: What Gap? Which Gap?" *Foreign Policy*, Fall 1978, p. 91.

[8]"Heel Marks at the Edge of the Cliff," *The Stanford Magazine*, Vol. 10, No. 3, Fall 1982, p. 21.

[9]Walter Isaacson, "The Winds of Reform," *Time*, March 7, 1983, p. 12-30.

[10]Cooper, "The Coming Revolution in Conventional Weapons," pp. 75, 84.

[11]Holzman and Portes, "Trade, Technology, and Leverage: The Limits of Pressure," p. 64.

[12]Rex V. Brown; Andrew S. Kahr; and Cameron Peterson, *Decision Analysis: An Overview*, (New York: Holt, Reinhart and Winston, 1974), p. 4.

[13]Fallows, *National Defense*, p. 35.

[14]Ibid.

[15]Ibid. p. 34.

[16]Willis M. Hawkins, "Lessons from Aerospace," *Astronatics and Aeronautics*. Vol. 20, No. 10, October 1982, p. 71.

[17]Fallows, *National Defense*, p. 172.

[18]Course Notes, *Technology and Strategy*, (National War College: Washington, D.C.), Fall 1982.

## FOOTNOTES

### CHAPTER III (Pages 16-25)

[19] Lieutenant General James H. Merryman, "Creativity in U.S. Army Acquisition," Speech, National War College, Washington, D.C.: 7 December 1982, (permission granted by Lieut. Gen. Merryman to use these excerpts in this paper).

[20] Ibid.

[21] David D. Archer, and George R. McAleer Jr., "The Acquisition Process: New Opportunities for Innovative Management," Concepts, Summer 1982, p. 83.

[22] Weinberger, Annual Report to the Congress, pp. 80, 81.

[23] Ibid., p. 81.

[24] Ibid., p. 47.

[25] Ibid.

[26] Air Force Association Policy for 1983, p. 4.

[27] Weinberger, Annual Report to the Congress, p. 47.

## FOOTNOTES

### CHAPTER IV (Pages 26-38)

[1]Hawkins, "Lessons from Aerospace," p. 11.

[2]Ibid., pp. 66, 68.

[3]David D. Acker, "Independent R & D: Key to Technological Growth," Defense Systems Management Review, Winter 1980, p. 48.

[4]Ibid., p. 56.

[5]George A, Keyworth II, "The Federal Role in R & D," Research Management, January 1982, p. 7.

[6]William H. Gregory, "Squeezing Research," Aviation Week and Space Technology, January 10, 1983, p. 11.

[7]Clarence A. Robinson, Jr., "Opponents Plan Drive on Research," Aviation Week and Space Technology, January 10, 1983, p. 18.

[8]Weinberger, Annual Report to the Congress, p. 269.

[9]Hawkins, "Lessons from Aeropace," pp. 68-69.

[10]Gansler, The Defense Industry, p. 104.

[11]Ibid.

[12]Ibid., p. 105.

[13]Fallows, National Defense, p. 175.

[14]Weinberger, Annual Report to the Congress, p. 278.

[15]Augustine, Augustine's Laws, p. 9.

[16]Gansler, The Defense Industry, p. 106.

[17]Robert B. Rosenfeld, "Idea Evaluation in a Large Industrial Organization," Unpublished Paper, Eastman Kodak Company, Rochester New York, 1981.

[18]Robert J. Hermann, "USDRE Independent Review of DOD Laboratores," Prepared for Under Secretary of Defense for Research and Engineering, (Washington, D.C.), March 22, 1982, p. 2-1.

[19]Air Force 2000, p. 244.

## FOOTNOTES

### CHAPTER IV (Pages 26-38)

[20]Hermann, "USDRE Independent Review of DOD Laboratories," p. 3-2.

[21]Gansler, The Defense Industry, p. 108.

[22]Air Force 2000, p. 244.

[23]Clarence A. Robinson, Jr., "DeLauer Urges Technology Spending," Aviation Week and Space Technology, September, 1982, p. 257.

[24]Ibid.

[25]George A. Keyworth II, "The Federal Approach to Defense Systems," Astronautics and Aeronautics, Vol. 20, No. 9, September 1982, p. 30.

[26]Ibid.

[27]Ibid.

[28]Ibid., and Robinson, "DeLauer Urges Technology Spending," p. 257.

[29]Hermann, "USDRE Independent Review of DOD Laboratories," p. 2-1.

[30]Air Force 2000, p. 244.

[31]Air Force Association Policy for 1983, p. 10.

[32]Keith Collier, "ASD-AFWAL Major Thrusts," 5 January 1983 briefing. Wright-Patterson AFB, Ohio.

[33]Morton, Organizing for Innovation, p. 50.

[34]Lieutenant Colonel Robert W. Bargmeyer, Student Syllabus for Laboratory Management of Research and Development, Sys 420, Air Force Institute of Technology, Wright-Patterson AFB, Ohio, March, 1982, pp. 14, 15.

[35]Morton, Organizing for Innovation, p. 63.

## FOOTNOTES

### CHAPTER V (Pages 39-50)

[1]Harry Levinson, Executive (Cambridge: Harvard University Press, 1981), p. 207.

[2]U.S. Panel on Invention and Innovation, Technological Innovation: Its Environment and Management, U.S. Government Printing Office, Washington, D.C. 1967, p. 2.

[3]"The Kirton Adaptation-Innovation Inventory," Used at the National Defense University, Fall 1982.

[4]Ibid.

[5]Twiss, Managing Technological Innovation, p. 12.

[6]Gansler, The Defense Industry, p. 101.

[7]Galbraith, "Designing the Innovating Organization," p. 16.

[8]Ibid., p. 14.

[9]Thomas W. Jackson and Jack M. Spurlock, Research and Development Management, (Homewood, Illinois: Dow Jones-Irwin, 1966) p. 98.

[10]See discussion in references such as: George M. Prince, The Practice of Creativity (New York: Collier, 1970);

Alex F. Osborn, Applied Imagination, (New York: Charles Scribner's Sons, 1979);

James L. Adams, Conceptual Blockbusting, (New York: W.W. Norton, 1979); and

James D. Lang, "Organizing and Training for Innovative Flight Test Management," American Institute of Aeronautics and Astronautics, Paper No. 81-1214, 1981.

[11] George S. Odiorne, The Change Resisters, (Prentice-Hall, 1981), p. 29.

[12]Galbraith, "Designing the Innovating Organization," p. 21.

[13]Jackson and Spurlock, Research and Development Management, p. 51.

[14]Ibid., p. 55.

FOOTNOTES

CHAPTER V (Pages 39-50)

[15]"Going for the Gaps," The Stanford Magazine, Vol. 10, No. 3, Fall 1982, p. 38.

[16]Ibid., p. 40.

[17]Marvin J. Cetron and Joel D. Goldhar, eds., The Science of Managing Organized Technology, Vol. 4, (New York: Gordon and Breach, Science Publishers, 1970), p. 1330.

[18]Ibid.

[19]"Going for the Gaps," The Stanford Magazine, p. 41.

[20]Osborne, Applied Imagination, p. 353.

[21]"Heel Marks at the Edge of the Cliff," The Stanford Magazine, p. 21.

[22]Odiorne, The Change Resisters, p. 38.

[23]Cetron, The Science of Managing Organized Technology, p. 1497.

[24]Augustine, Augustine's Laws, p. 15.

[25]Morton, Organizing for Innovation, p. 33.

[26]Galbraith, "Designing the Innovating Organization," p. 5.

[27]U.S. Panel on Invention and Innovation, Technological Innovation: Its Environment and Management, p. 29.

[28]Galbraith, "Designing the Innovating Organization," p. 6.

[29]Adams, Conceptual Blockbusting, p. 143.

[30]Morton, Organizing for Innovation, p. 3.

[31]Cetron and Goldhar, The Science of Managing Organized Technology, p. 1331.

[32]Roger Fisher and William Ury, Getting to Yes: Negotiating Agreement Without Giving In, (Boston: Houghton Mifflin, 1981), p. 61.

[33]Twiss, Managing Technological Innovation, p. 104.

## FOOTNOTES

### CHAPTER V (Pages 39-50)

[34]Catron and Goldhar, The Science of Managing Organized Technology, p. 1564.

[35]Interview with Peter B. Vaill, Professor of Human Systems, George Washington University, Washington D.C.: 13 December 1982.

[36]Thomas J. Peters, "Putting Excellence into Management," Business Week, July 21, 1980, pp. 196-205.

[37]Twiss, Managing Technological Innovation, p. 104.

[38]Galbraith, "Designing the Innovating Organization," p. 14.

[39]Prince, The Practice of Creativity, p. 208.

[40]Osborn, Applied Imagination, p. 353.



☆ U.S. GOVERNMENT PRINTING OFFICE : 1983 O - 425-560 (41)

END

FILMED

3-84

DTIC